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ABSTRACT

This curriculum guide contains lecture outlines and handouts for training solar technicians in the installation, maintenance, and repair of solar energy hot water and space heating systems. The curriculum consists of four modular units developed to provide a model through which community colleges and area vocational/technical schools can respond to training requirements and manpower needs as the market for solar systems progresses. The four units can serve as an extension of an existing occupational program or as a short-term intensive training program for individuals engaged in the heating and air conditioning industry. The four units include solar radiation and introduction to solar technology, solar construction techniques and materials, solar domestic hot water systems, and solar space heating systems. Each unit consists of performance objectives, presentation, training aids, and references; and some units contain learning activities. Twenty handouts for students cover the following topics: the earth's orbit, solar energy, heat transfer, Kansas laws concerning energy conservation and solar energy systems, terminology, basic systems, safety, soldering and brazing, symbols, valves, pumps, availability of solar energy, residential hot water requirements, design calculations, direct heating--thermosiphon system, direct heating--pumped system, indirect heating--pumped system with heat exchanger, active solar heating and cooling, common operating modes, and common problems. (Author/KC)

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Cornett E. Hall
Director of Occupational Education

Dr. James E. Hooper
President

ABSTRACT

TITLE OF PROJECT: Solar Curriculum Development in State Community Colleges and Area Vocational/Technical Schools.

APPLICANT ORGANIZATION: Seward County Community College, Liberal, Kansas 67901.

PROJECT DIRECTOR: Cornett E. Hall, Director of Occupational Education.

DURATION OF PROJECT: July 1, 1979 - June 30, 1980.

This report contains lecture outlines and handouts for training solar technicians in the installation, maintenance and repair of solar energy systems. The curriculum consists of four modular units developed to provide a model through which community colleges and area vocational/technical schools can respond to training requirements and manpower needs as the market for solar systems progresses. The four units can serve as an extension of an existing occupational program or as a short-term intensive training program for individuals engaged in the heating and air-conditioning industry.

INTRODUCTION

With the signing of the National Energy Act, the United States has made a significant commitment to the exploration and development of solar technology as an alternative energy source during the next decade. Associated with such a commitment is a corresponding need for skilled solar workers and technicians, although the exact extent of this requirement is yet unknown. Nonetheless, the development of specific vocational education and continuing education programs to train individuals in installing, repairing, replacing, adjusting and even modifying solar and solar assisted energy systems should be a concern at this time, if the needs of the next decade are to be met.

Community colleges, working in close cooperation with area vocational-technical schools, are in a unique position to address these training requirements. With this in mind, the following curriculum was developed as a guide for either a short-term training program or an extension of an existing program.

PROGRAM OUTLINE

Unit 1.	Solar Radiation and Introduction to Solar Technology	16 hours
Unit 2.	Solar Construction Techniques and Materials	24 hours
Unit 3.	Solar Domestic Hot Water Systems	30 hours
Unit 4.	Solar Space Heating Systems	40 hours

The essential training objective is to provide the heating and air conditioning technician or vocational student with a fundamental knowledge of solar assisted space heating and domestic solar hot water systems in order that the individual may advance in design, installation and service responsibilities as the market for solar systems progresses.

The four units can be incorporated into an existing vocational-technical program, offered as a short-term intensive training program, or included in a continuing education or occupational education program. While the individual units can be presented as stand-alone courses, it is recommended that Unit 1 be a prerequisite for the other units.

UNIT 1: SOLAR RADIATION AND INTRODUCTION TO SOLAR TECHNOLOGY

This unit describes the nature of solar radiation and the composition of solar rays, and explains the basic concepts, system types and economic considerations involved with solar heating.

I. Performance Objectives

A. Define solar energy.

B. Explain the factors which affect the availability of solar radiation at the earth's surface.

C. Describe the difference between direct and diffuse radiation.

D. Explain the various units of measure used to report solar radiation.

E. Locate sources of solar data and convert solar radiation from one unit of measure to another using standard conversion factors.

F. Explain how heat is transferred from one medium to another.

G. Name the major components of a solar heating system.

H. Point out the difference between air and liquid systems.

I. Explain the difference between active and passive systems.

J. Discuss the basic expectations of performance, economic implications, advantages and disadvantages of the various types of systems and components.

II. Presentation

A. Solar Theory

1. Explain the changing relationship of the sun to the earth as the earth rotates in an orbit around the sun: earth's orbit, solar altitude, solar azimuth, sun path, latitude and declination, sun charts. (Handout No. 1)

2. Explain how thermal radiation is measured and how to determine the amount of solar radiation available for a given period of time: direct and diffuse radiation, insolution, Langleys, British Thermal Units, calories, kilowatt-hours. (Handout No. 2)

3. Explain the science of heat flow through materials and space: conduction, radiation, convection, thermal resistance, heat gains and losses. (Handout No.3)

B. Solar Technology

1. Discuss the historical development and government involvement in solar technology: history of solar energy development, OPEC oil embargo, Energy Research and Development Administration, The Heating and Cooling Act of 1974, U.S. Department of Energy, 1978 National Energy Act, energy legislation in Kansas. (Handout No. 4)

2. Discuss terminology, describe the main elements of a solar heating system, and explain the function and operation of individual components: collector, storage, distribution, transport, controls, auxiliary energy, active and passive systems, air and liquid systems. (Handout No. 5)

3. Describe practical applications and systems under development with possible future promise: domestic hot water systems, swimming pool heating systems, space heating systems, solar cooling systems, agriculture and industrial applications, solar cells, space power stations, solar farms, basic expectations of performance, economic implications. (Handout No. 6)

III. Training Aids

A. "Look To The Sun", 16 mm, 12½ minutes, DOE-TIC, P.O. Box 62, Oak Ridge, TN 37830.

B. "Solar Energy", 16 mm, 13½ minutes, Montage Educational Films, P.O. Box 33992, Seattle, WA 98133.

C. "Harvest Of The Sun", 16 mm, 15 minutes, Audio Visual Services, Office of Educational Media, Colorado State University, Fort Collins, CO 80523.

D. "Solar Power: The Giver of Life", video cassette, 29 minutes, University of Colorado Education Media Center, Stadium Building, Bouler, CO 80309.

E. "Solar Demonstration Projects", video cassette, 60 minutes, ITT Center, Chicago, IL 60616.

IV. References

A. Strahler, Arthur N., Strahler, Alan H., Introduction to Environmental Science. Santa Barbara, California: Hamilton Publishing Company.

B. Bueche, F., Principles of Physics, Third Edition. New York: McGraw-Hill, Inc.

C. Ewers, William I., Solar Energy--A Biased Guide. Northbrook, Illinois: Domus Books.

UNIT 2: SOLAR CONSTRUCTION TECHNIQUES AND MATERIALS

This unit describes the fundamental operations and principles of metal-working, soldering, brazing and glazing; and discusses basic materials and components used in the construction and installation of solar heating systems.

I. Performance Objectives

A. Discuss safety procedures and precautions.

B. Demonstrate the proper use of various torches and tools.

C. Demonstrate the ability to perform basic metal-working, solderint, brazing and glazing operations.

D. Select the proper solder or brazing alloy for a specific job.

E. Explain the classification of pipe fittings.

F. Explain piping design and pump selection.

G. Discuss the use of and installation precautions for various types of valves.

H. Identify common electrical and piping symbols.

II. Presentation

A. Basic Skills

1. Discuss safety equipment and precautions: housekeeping; basic safety rules for using tools and equipment; goggles, gloves and clothing; potential dangers and hazards in handling and working with liquids, gases and other materials; toxic fumes and ventilation. (Handout No. 7)

2. Describe and demonstrate the metal-working, joining and glazing operations necessary to construct a typical solar collector.

a. Extruded aluminum framing: handling and

storage, cleaning, mechanical fastening, drilling, sawing, saw blade selection.

b. Glazing: face glazing, single glazing, dual glazing, edge clearance, nominal cover, setting block, gasket spacing.

c. Torch soldering and brazing. (Handout No. 8)

(1) Equipment; description, tip size, lighting, torch adjustments, torch positions and movement, shutting off torch.

(2) Principles and procedures: alloys, fluxes, cleaning, supporting the assembly, fluxing, heating and flowing the the alloy, cleaning after soldering or brazing, joint inspection and testing.

3. Valves, Pumps and Materials

1. Explain valve types, installation precautions and use: air relief, backflow preventer, ball, check, combination temperature, pressure, drain, flow-control, gate, globe, isolation, manual shut-off, pressure relief, snifter, solenoid, tempering. (Handout No. 10)

2. Explain piping design and pump selection: line pressure, flow rate, head losses, pump operation, pump location, distinguishing between open and closed systems, calculating system flow and pressure loss requirements, adapting pumps to higher head requirements, use of high heat transfer fluids. (Handout No. 11)

3. Explain terms, provide price information and give sources of supply for common materials: extruded and sheet aluminum; copper sheets, tubing and fittings; double-strength, tempered and insulating glass; desiccants and sealing compounds; fasteners; insulation; paint; heat transfer fluids; sensors and controls.

III. Materials

A. Oxyacetylene, acetylene or propane torch

B. Hacksaw

C. Metal reamer

D. Tube cutter

E. Glass cutter

F. Power drill

G. Power saw (skill, sabre and radial arm)

H. Copper tubing and fittings

I. Solder type 50A

J. Sil-Fos brazing alloy

K. Emery cloth

L. Paste flux

M. Aluminum frame extrusion

N. Neoprene setting blocks

O. Glazing tape

P. Silicone sealant

Q. Double-strength window glass

R. Miscellaneous materials depending upon student projects

IV. Activities

A. Laboratory activities should constitute approximately 60% of this unit. Depending on number of students and availability of equipment, students may be rotated through different work stations, assigned specific work stations and all work on the same type of project at the same time, or divided into groups and work on a larger project such as building a flat-plate collector.

V. Training Aids

A. "Installing Solar Heating and Domestic Hot Water Systems", 75 slides, 35 mm, with 15 minute audio cassette, National Solar Heating and Cooling Information Center, P.O. Box 1607, Rockville, MD 20805.

B. "Solar Installation Special Techniques", 40 slides, 35 mm, Solar-Ed Corporation, Solar Energy Curriculum Materials, 1627 Lichfield Turnpike, P.O. Drawer X, Woodbridge, CT 06525.

VI. References

A. Althouse, Turnquist, Bowditch, Modern Welding. South Holland, Illinois The Goodheart-Willcox Co., Inc.

B. Solar Industry Index. Solar Energy Industries Association, 1001 Connecticut Ave. N.W., Ste 632, Washington, D.C. 20036.

C. Martz, C.W., Solar Energy Source Book. Solar Energy Institute of America, 1140 6th St. N.W., Washington, D.C. 20001.

D. Glazing Manual. Flat Glass Marketing Association, Topeka, Kansas.

E. Sosnin, H.A., The Theory and Technique of Soldering and Brazing Piping Systems. NIBCO Inc., Elkhart, Indiana.

F. "How to Specify Pumps for Solar Systems". Grundfos Pumps Corporation, 2555 Clovis Ave., CA 93612.

UNIT 3: SOLAR DOMESTIC HOT WATER SYSTEMS

This unit describes three basic types of domestic solar hot water systems; considers each of the principle components of the systems individually; discusses the operation of the systems; presents information about system design and layout; and deals with installation, maintenance and servicing procedures and responsibilities.

I. Performance Objectives

A. Compute the amount of hot water required for a given residence.

B. Compute the size of the collector required for a typical residential installation.

C. Describe the operation and identify the components of three different types of solar hot water systems.

D. Design and layout of three different systems.

E. Identify periodic maintenance procedures for various components of a solar assisted hot water system.

F. Discuss maintenance problems that are common among solar hot water systems, and explain troubleshooting procedures.

G. Explain the hazards associated with solar hot water systems and discuss those aspects that relate to the health and safety of the owner or occupant.

H. Discuss building codes and zoning requirements.

II. Presentation

A. Basic Considerations

1. Discuss basic design considerations: mean daily solar radiation, climatic zones, quality of insolation, path of the sun, orientation of the collector, shading factors. (Handout No. 12)

2. Explain how to determine residential water requirements: hot water service temperature, supply temperature, personal use and appliance requirements. (Handout No. 13)

3. Explain calculations used to develop design parameters: energy requirements, average monthly load, average daily radiation, collectable energy collector efficiency, line and tank losses, usable energy, size of collector and tank. (Handout No. 14)

B. Solar Hot Water Systems

1. Describe and explain three basic types of domestic solar hot water systems: preferred climatic zones, system description and operation of components, design examples, materials, and installation.

   a. Direct heating, thermosiphon system. (Handout No. 15)

   b. Direct heating, pumped system. (Handout No. 16)

   c. Indirect heating, pumped system with heat exchanger. (Handout No. 17)

2. Explain servicing requirements and procedures: installation start-up, periodic maintenance, troubleshooting, common problems, warranties.

3. Discuss responsibilities of those who design, engineer, install and use solar hot water systems: health and safety, protection of property, building codes and zoning requirements, quality standards, and assurances.

III. Training Aids

A. "Installing Solar--Some Early Lessons Learned", 30 minutes, 16 mm, Time-Life Multimedia, Distribution Center, 100 Eisenhower Drive, Paramus, NJ 07652.

B. "Installing Solar Heating and Domestic Hot Water Systems", 75 slides, 35 mm, 15 minute audio cassette, P.O. Box 1607, Rockville, MD 20850.

C. "Measurement and Control Systems", 25 slides, 35 mm; "Solar Installation Special Techniques", 40 slides, 35 mm; Sennergetics, 18621 Parthenia Street, Northridge, CA 91324.

D. "Flat-Plate Solar Collectors, Part I and Part II", videotape, 116 minutes; "Design and Installation of Solar Heating and Cooling Systems, Part I and Part II", videotape, 104 minutes; ITT/V, ITT Center, Chicago, IL 60616.

IV. References

A. Kreith, F., Kreider, J.F., Principles of Solar Engineering. Washington, DC: Hemisphere Publishing Corporation.

B. Basics of Solar Heating and Hot Water Systems, AIA Research Corporation, Washington, DC 20006.

C. Solar Industry Index. Solar Energy Industries Inc., 1001 Connecticut Ave., NW, Ste. 632, Washington, DC 20001.

UNIT 4: SOLAR SPACE HEATING AND COOLING SYSTEMS

This unit describes the basic concepts of solar heating and cooling systems; explains the function of system components; discusses system operation and sizing of components; outlines factors to consider in the installation of a system; and presents information about maintenance requirements and procedures.

I. Performance Objectives

A. Name the major components of a solar heating and solar cooling system, and describe the basic expectations of performance of the different types of systems.

B. Describe the operating principles of various components in the collector, and explain the differences in how air and liquid collectors are designed.

C. Identify advantages and disadvantages of various heat storage practices, and explain the concepts of sizing a heat storage unit.

D. Identify and describe the function and operating principles of the various specialty items and control devices used in solar heating and cooling systems.

E. Discuss the five basic modes of operation for an air solar heating and cooling system, and identify which components should be operating and which valves or dampers should be open during each operating mode.

F. Size a solar heating system for a specific application, and complete a materials list.

G. Discuss the architectural problems related to installing solar heating and cooling systems, describe the sequence of activities for installation scheduling and demonstrate a familiarity with common installation practices.

H. Explain general start-up procedures for air and liquid systems, list preventative maintenance procedures for various components, and discuss common problems and trouble shooting procedures.

II. Presentation

A. Introduction to Solar Heating and Cooling. (Handout No. 18)

1. Discuss basic concepts, system types and system components: active and passive systems, collectors, heat storage, auxiliary heating, solar cooling, economics.

2. Explain the function, the various types and the design of solar collectors: flat plate, concentrating, transparent covering, absorber plate, heat transfer systems, insulation, frame, flow rates, efficiency.

3. Describe the methods and explain the concepts of heat storage: heat storing materials, sizing, placement, advantages and disadvantages of various storage units.

4. Discuss the various controls and speciality items of a solar heating and cooling system: pumps, heat exchangers, blowers, controllers, thermostats, sensors, valves, dampers, other miscellaneous items.

B. Operation of Solar Heating and Cooling Systems and Sizing of Components

1. Describe the more common types of air and liquid solar heating systems, and explain the basic modes of operation: air systems, hydronic systems, heating from collector, heating from storage, auxiliary heating, storing heat, cooling, controlling the sequence of operations, design and installation factors. (Handout No. 19)

2. Explain the considerations and techniques for sizing the components of a solar heating and cooling system: sizing solar collectors; sizing the heat storage unit; sizing fans, pumps, ducts and pipes; life-cycle-costs.

C. Installation and Servicing

1. Discuss the factors to be considered in the installation of collectors, heat storage units, control devices and speciality items: new construction, retrofitting, standards, guidelines, scheduling activities.

2. Identify and explain servicing procedures for solar heating and cooling systems: installation start-up, system balancing, periodic maintenance, troubleshooting, part failure, adjustments, emergency repairs, common problems. (Handout No. 20)

III. Activities

If facilities or systems are available, the following student activities are recommended:

A. Perform a "systems check" and an "operations check" of an operational system.

B. Investigate and/or test commercially marketed devices and materials to establish effect and possible return on investment.

C. Perform periodic inspection and preventative maintenance procedures.

D. Demonstrate proper use of appropriate measuring equipment, tools and test instruments.

IV. Training Aids

A. "Building Solar: An Introduction to Active System Installation in Homes", 16 mm, 20 minutes, "Installing Solar Heating and Domestic Hot Water Systems", 75 slides, 35 mm, 15 minute audio cassette, National Solar Heating and Cooling Information Center, P.O. Box 1607, Rockville, MD 20850.

B. "Commercial Solar Installations", 40 slides, 35 mm, audio cassette, Solar Engineering Magazine, 8435 N. Stemmons Freeway, Suite 880, Dallas, TX 75247.

C. "Thermal Storage System", 60 minutes, videotape, "Design and Installation of Solar Heating and Cooling Systems, Part I and II", 112 minutes, videotape, ITT/F, ITT Center, Chicago, IL 60616.

D. "Solar Installation Special Techniques", 40 slides, 35 mm, Solar-Ed Corporation, Solar Energy Curriculum Materials, 1627 Litchfield Turnpike, P.O. Drawer X, Woodbridge, CT 06525.

V. References

A. Kreith, F., Kreider, J.F., Principles of Solar Engineering. Washington, DC: Hemisphere Publishing Corporation.

B. Win, C.B., et al, Solar Heating and Cooling of Residential Buildings: Design of Systems. Solar Energy Applications Laboratory, Colorado State University.

C. Ward, D.S., et al, Solar Heating and Cooling of Residential Buildings: Sizing, Installation and Operation of Systems. Solar Energy Applications Laboratory, Colorado State University.

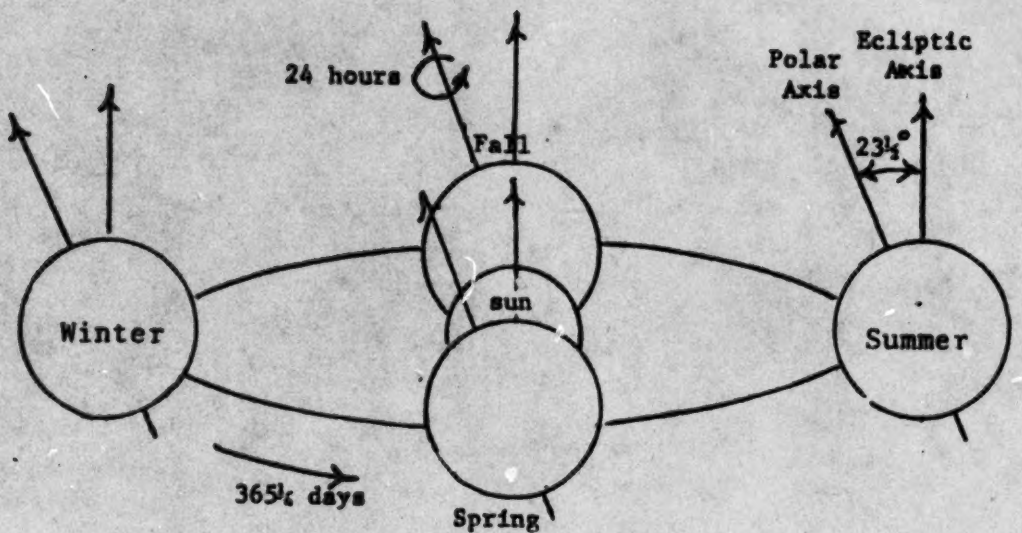
D. Fundamentals of Solar Heating, Sheet Metal and Air Conditioning Contractors National Association, NTIS, Springfield, VA 22161.

HANDOUT 1: THE EARTH'S ORBIT

The two major movements of the earth are rotation (on its axis) and revolution (around the sun). Knowledge of these movements and the way they affect the earth's relationship to the sun is basic to an understanding of the distribution of solar energy over the surface of the earth.

The earth rotates on its axis, making one complete turn in approximately 23 hours, 56 minutes and 4 seconds. The earth also revolves around the sun in an elliptical orbit. The average speed of revolution is about 70,000 miles per hour, and the average time to complete a revolution in orbit is about 365¼ days.

The earth's axis is tilted away from the perpendicular to the plane of its orbit around the sun at an angle of 23½ degrees (inclination), and the axis of the earth at any given position in its orbit is parallel to its axis at any other position (parallelism). Because of these two conditions, the angle of the sun's rays at any location on the earth and the length of day and night vary from one season to another. See the diagram on the following page.


24 hours
Fall
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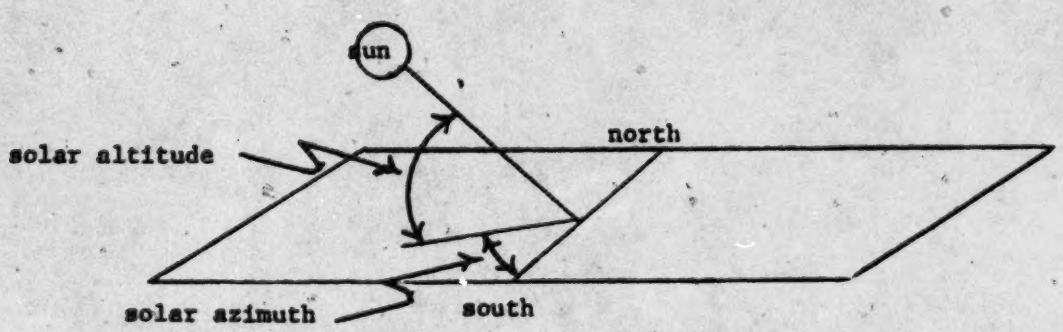
Summer
365¼ days
Spring


sun
north
solar altitude
solar azimuth
south

HANDOUT 2: SOLAR ENERGY

The source of solar energy is in the sun's interior where hydrogen is converted to helium. In this nuclear fusion process, a vast quantity of heat is generated and finds its way by convection and conduction to the sun's surface. The highly heated, incandescent gas that comprises the sun's surface emits a form of energy known as electromagnetic radiation. This solar radiation spectrum consists of X-rays, gamma rays, ultraviolet rays, visible light rays and infrared rays.

Temperature conditions at the surface of the earth vary greatly with place and time. These variations are a result of: the angle of the sun's rays, length of day, nature of the surface, atmospheric conditions, fluctuations in solar radiation and variations in the distance from the earth to the sun. The first three causes have the most significance.

Manuals published by the American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc. (ASHRAE) contain tables showing the amount of solar radiation during each month of the year at various latitudes. The following definitions are helpful in interpreting the various graphs and tables.

DIFFUSE RADIATION--solar radiation which has been scattered by constituents of the atmosphere and re-directed onto the earth's surface.

DIRECT RADIATION--solar radiation associated with the direct solar beam from the direction of the sun's disc.

INSOLATION--the total solar radiation, direct and diffuse, falling on a surface.

LATITUDE--lines, running true east-west around the globe, used to measure distances north and south of the equator.

SOLAR ALTITUDE--the angle, above the horizontal, of the position of the sun.

SOLAR AZIMUTH--the angle, along the horizontal, of the position of the sun relative to true south.

SOLAR POSITION--the sun's apparent position from any point on earth as specified by two angles, altitude and azimuth.

SOLAR TIME--the time according to the position of the sun. For a given location and a given day, noon is calculated as the instant the sun reaches its zenith or highest point.

BRITISH THERMAL UNIT (BTU)--the amount of heat required to raise one pound of water through one degree Fahrenheit.

CALORIE--the amount of heat required to raise one gram of water through one degree Celsius (Centigrade).

FOOT-POUND--the amount of work done when a constant force of one pound is exerted on a body which moves a distance of one foot in the same direction as the force.

HEATING DEGREE DAY--a statistical device used to estimate fuel consumption, defined as a one degree Fahrenheit departure of the daily mean temperature below 65°F.

HORSEPOWER--a unit of power which is the rate at which work is done and is equivalent to 550 ft-lb/sec.

JOULE--the amount of work done when a constant force of one newton is exerted on a body which moves a distance of one meter in the same direction as the force.

LANGLEY--a unit of energy frequently used in radiation work and is equivalent to 1 calorie/cm^2.

WATT--a unit of power which is the rate at which work is done and is equivalent to one joule per second.

1 Btu = 1.05506×10^3 joule (J) = 778.169 ft-lb

1 calorie (cal) = 4.1868 J

1 kilocalorie = 3.96830 Btu

1 Watt = 1 Joule per second = 0.00134 horsepower

1 kilowatt hour (kwh) = 3.600×10^6 J = 3.41213×10^3 Btu

1 Btu/h = 0.293071 W

HANDOUT 3: HEAT TRANSFER

Heat, which is one of the most common forms of energy, is continually being transferred from one body to another. The three ways in which heat is transferred are by conduction, convection and radiation.

CONDUCTION--the simplest mode of heat transfer, takes place in a body when different parts of the body are at different temperatures. The direction of heat flow is always from points of higher to points of lower temperature. The rate of flow of heat (H) through any body by conduction is proportional to the area (A), the temperature difference $(t_2 - t_1)$, the kind of material (K), and inversely proportional to the thickness (L). Stated in equation form:

$$H = KA(t_2 - t_1)/L$$

The quantity K is called the coefficient of thermal conductivity or simply the thermal conductivity of the material. A material for which K is large is a good heat conductor, while if K is small, the material is a poor conductor or a good insulator. Representative values of thermal conductivity, expressed in units of cal/sec cm C^o, are as follows:

Silver	.97
Lead	.083
Concrete	.002
Water	.0014
Wood	.0003
Air	.00005

CONVECTION--the transfer of heat from one place to another by actual motion of the hot material. The hot-air furnace and hot-water heating system are examples. If the heated material is forced to move by a blower or pump, the process is called "forced convection". If the material flows due to differences in density, the process is called "natural" or "free convection". In most fluids, a rise in temperature is accompanied by a decrease in density. Therefore, if heat is applied at the bottom of a sample, the less dense fluid at the bottom is continually displaced by fluid of greater density from above.

Because convection is a very effective method of heat transfer, it must be considered in designing a system of insulation. The insulating materials should not only be poor conductors in themselves, but they should also leave many small air spaces, which are also poor conductors and at the same time are so small that no effective convection currents can be set up.

The mathematical theory of heat convection is quite involved and there is no simple equation, as there is for conduction. However, a case of common occurrence is that of natural convection from a wall at a constant temperature, surrounded by air at atmospheric pressure and differing in temperature. The heat gained or lost by convection (H) by the surface of area (A) with a convection coefficient (h)

and a temperature difference Δt can be calculated from the equation:

$$H = hA\Delta t$$

RADIATION--refers to the continual emission of energy from the surface of all bodies, and the transfer of heat by radiation does not require a material medium for the process. This energy is called "radiant energy" and is in the form of electromagnetic waves which travel with the velocity of light and are transmitted through a vacuum as well as through air. When they fall on a body which is not transparent to them, such as a solar collector, they are absorbed and their energy is converted to heat. Objects whose surfaces are in such condition that they are good absorbers of radiation are also good radiators. Likewise, a poor emitter is a good reflector.

As an example, the glass roof of a greenhouse is transparent to the visible and near-infrared radiations from the sun and admits them. The energy is absorbed by objects inside the greenhouse and converted to heat. Since the temperature of the objects in the greenhouse is not high, their heat radiation is not identical with the radiation that entered. The glass does not transmit this radiation, and the greenhouse acts as an energy trap. This is called the "greenhouse effect" and is the principle upon which solar heated houses operate.

HANDOUT 4: KANSAS LAWS CONCERNING ENERGY CONSERVATION AND SOLAR ENERGY SYSTEMS

Solar Income Tax Credit (1976). K.S.A. 79-32, 166 permits both individuals and businesses to claim a state income tax credit for part of the cost of solar energy systems installed in Kansas between January 1, 1976, and July 1, 1983. For individuals who install solar systems for domestic purposes, the credit is equal to 25% of the installed system cost, with a maximum credit limit of $1,000. If an individual's tax obligation is less than the credit entitlement, the law permits the unused portion of the credit to be carried over and applied against the next year's income tax liability. If necessary, a total of five years can be used to exhaust the credit.

The credit allowed on commercial installations of solar equipment is also 25% of the installed system cost, but the maximum credit limit is higher, at $3,000. There is no carry-over feature for the commercial tax credit, but business firms may also elect to amortize the cost of the solar equipment over a 60-month period.

Wind energy systems used to produce electrical or mechanical power are specifically defined in the act as solar energy systems, and are therefore eligible for the credit.

Solar Property Tax Rebate (1977). K.S.A. 79-45a01 authorizes a partial rebate on property taxes paid on any building (or building addition) which is equipped with a solar energy system having the design capability of meeting at least 70% of the buildings heating or cooling requirements. The rebate,

which is to be paid by the state, is equal to 35% of total property taxes paid on the structure (excluding land), and it may be claimed each year for five years.

Provisions of the rebate law are effective only for taxable years 1978 through 1985, inclusive.

Solar Easements (1977). K.S.A. 58-3801 has the effect of requiring that all easements obtained for the purpose of securing access to sunlight must be in writing, and further, that they must be recorded with the appropriate register of deeds. The law also requires that the easement aggreement contain certain information concerning the dimensions of the easement, as specified in the law. It should be noted that this law does not attempt to define "solar rights" of property owners.

Solar Installations in State Buildings (1977). SCR 1601 was adopted by the 1977 Kansas Legislature, and directs the Secretary of Administration to consider the installation of solar energy heating and cooling systems for all new state-owned construction projects. The resolution also directs the Secretary to explore and consider the feasibility of establishing solar demonstration projects in existing state-owned buildings.

Alternate Energy Incentives for Utilities (1978). HB 2842, which was passed this year by the Legislature and approved by

the Governor, authorizes the Kansas Corporation Commission to allow jurisdictional utilities an additional ½ to 2 percent return on their investments in systems designed to generate or produce energy from renewable resources such as solar energy, geothermal energy, wind energy and biomass. The KCC is also authorized under the law to permit the higher rate of return on investments in experimental projects, such as load management equipment, designed to improve efficiency of energy use.

Income Tax Deduction - Insulation (1977). K.S.A. 79-32, 117 authorizes a state income tax deduction equal to 50% or $500, whichever is less, for the costs of labor and materials for retrofit installation in houses. In order to qualify for the deduction, the insulation materials used must meet the minimum standards applicable to new construction, as set by the Federal Housing Administration. Items such as caulking compound, storm doors and windows are not eligible for the deduction. The deduction cannot be used for costs of installing insulation in new houses.

Insulation Safety Standard (1978). SB 512, requires that all thermal insulation which is manufactured, distributed, sold or installed in the state must meet specified standards of flame retardation. Insulation must be proven to the State Fire Marshal to have a flame spread rating of 75 or less, and a statement to that effect must accompany the insulation product when it is offered for sale. City and county governments may

impose stricter standards with their respective jurisdictions.

Thermal Efficiency Standards - New Buildings (1978). HB 2698 extends the jurisdiction of the Kansas Corporation Commission to municipal, in addition to jurisdictional, utilities for the single purpose of ensuring that new buildings meet minimum standards of thermal efficiency. The effect of the law is to provide comprehensive state coverage of an order previously issued by the KCC which requires that all new buildings must meet certain thermal efficiency criteria before they can be hooked up to receive utility service. The order also sets minimum efficiency standards for new installations of air conditioning equipment and heat pumps.

HANDOUT 5: TERMINOLOGY

ABSORBER or ABSORBER PLATE--a surface, usually blackened metal, in a solar collector which absorbs solar radiation.

ABSORPTANCE--a measure of absorber plate efficiency, expressed as a percentage of total radiation that a given material will absorb.

ACTIVE SOLAR SYSTEM--a system in which an energy source, in addition to solar, is used for the transfer of thermal energy.

AUXILIARY SYSTEM--a system that provides the supply of energy when the stored solar energy is depleated.

COLLECTOR--the assembly used for absorbing solar radiation, converting it into useful thermal energy, and transferring the thermal energy to a heat transfer fluid.

COLLECTOR EFFICIENCY--a measure of the amount of insolation that can be collected at a given temperature over a given time.

COLLECTOR TILt--the angle measured from the horizontal, at which the solar collector is tilted to face the sun.

CONCENTRATOR--a reflector or lens used to focus solar radiation.

CONTROL SUBSYSTEM--the assembly of devices used to regulate the process of collecting, transporting, storing and utilizing solar energy.

EMITTANCE--a measure of the heat re-radiated back from the solar collector.

GALVANIC CORROSION--corrosion caused when different metals are not isolated properly and a liquid comes in contact with both metals.

HEAT EXCHANGER--a device for transferring thermal energy from one fluid to another.

HEAT TRANSFER FLUID--any substance such as air, water or antifreeze used to transport thermal energy.

HELIOSTAT--a mirror used to reflect solar radiation into a collector.

HYBRID SYSTEM--a system that uses both active and passive methods to operate.

PASSIVE SOLAR SYSTEM--a system in which collection, storage and distribution are achieved by natural heat transfer phenomena employing convection, radiation and conduction.

PHOTOVOLTAIC--direct conversion of the sun's energy into electricity.

PYRANOMETER--an instrument for measuring solar radiation.

SELECTIVE SURFACE--a special coating sometimes applied to the absorber plate in a solar collector for increasing absorptance and reducing emittance.

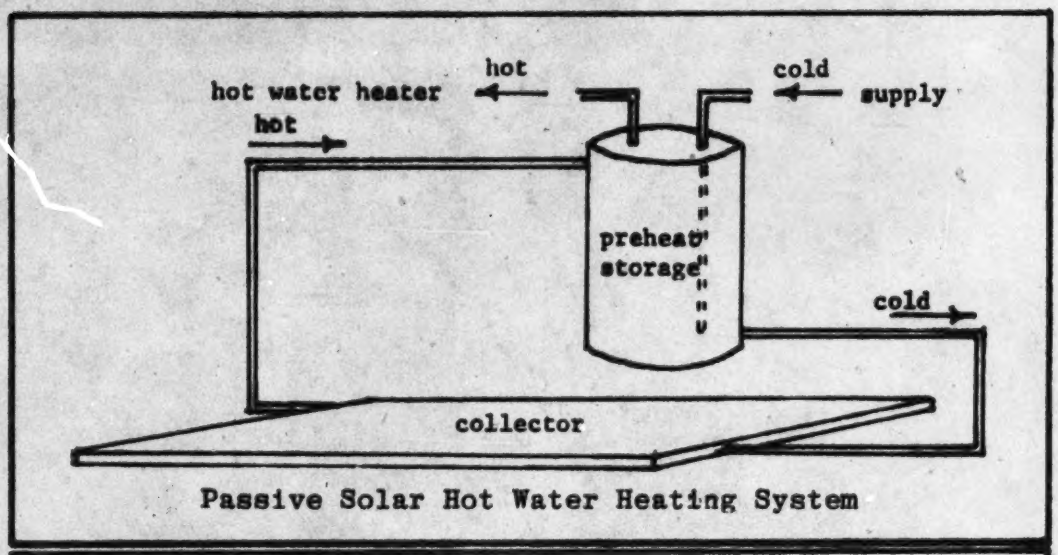
SOLAR CELL--a device, usually made of silicon, that converts sunlight directly into electrical energy.

STORAGE SUBSYSTEM--the assembly used for storing thermal energy so that it can be used when required.

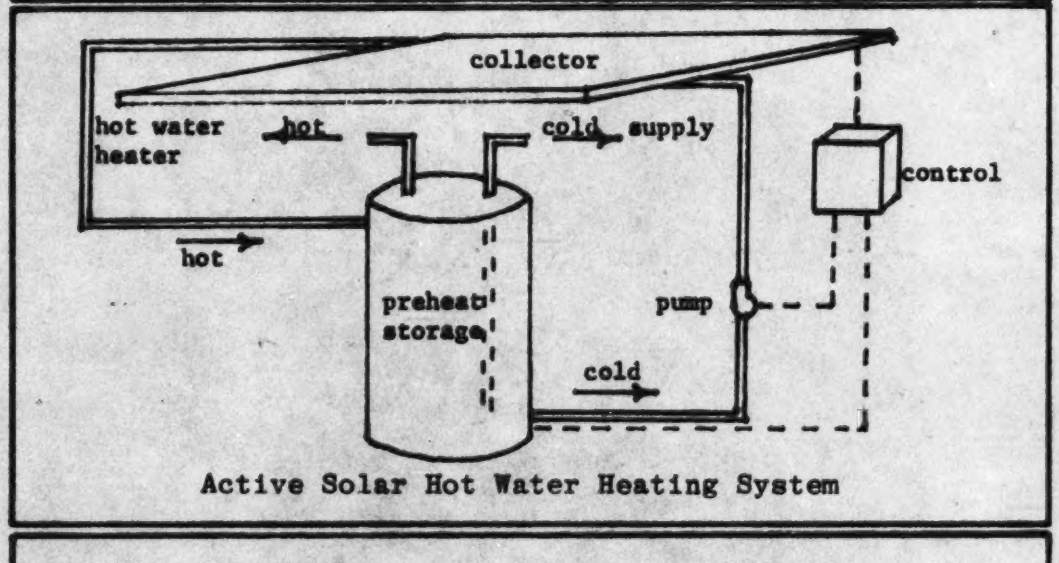
SUN TRACKING--following the sun with a solar collector to make the collector more effective.

THERMOSIPHON--the principle that makes water circulate automatically between a collector and a storage tank above it, gradually increasing its temperature.

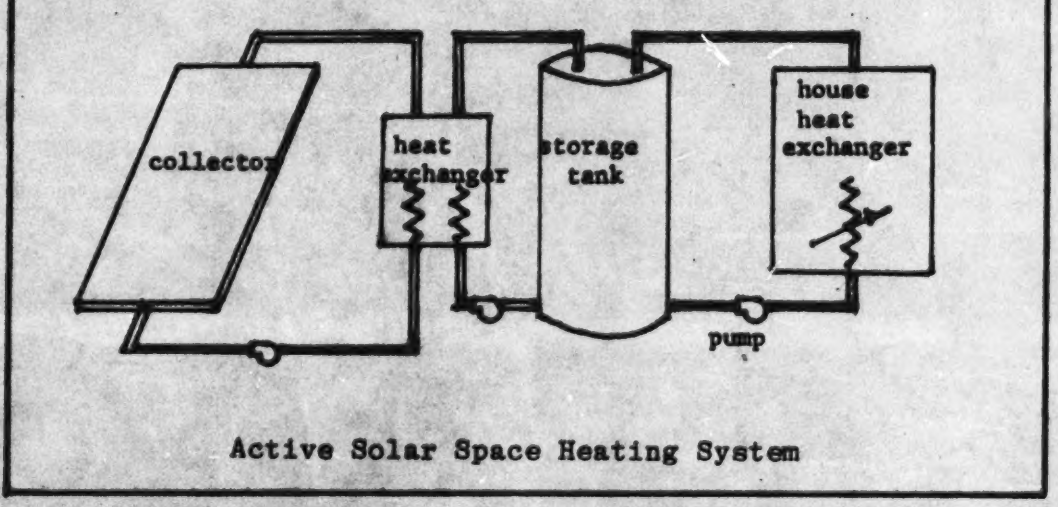
HANDOUT 6: BASIC SYSTEMS



Passive Solar Hot Water Heating System



Active Solar Hot Water Heating System



Active Solar Space Heating System

HANDOUT 7: SAFETY

1. Always extinguish a torch whenever it is not in your hands.
2. The torch hand valve should only be turned with the fingertips.
3. If a torch backfires, find the trouble and remedy it before continuing to use the torch.
4. Be careful that a torch is not directed toward another person while it is being lighted.
5. Safety goggles should be worn to protect the eyes and reduce glare.
6. Use a spark lighter for lighting the torch.
7. Be sure that no combustible material is in the area in which a torch is being lighted.
8. Use only fireproof materials for the support of articles being soldered or brazed.
9. Good ventilation is essential to eliminate health hazards which are presented by toxic metal and flux fumes.
10. Be sure that there are no flammable fumes such as gasoline, acetylene or other flammable gasses present where soldering or brazing is being performed.
11. Soldering or brazing with or on alloys containing cadmium, beryllium, tellurium, lead, mercury, antimony, arsenic, bismuth, and their compounds can be extremely hazardous. Fluxes containing fluoride compound are also toxic.
12. A common hazard when soldering or brazing is exposure of the skin, eyes, and clothing to acid fluxes. Always work in a way that flux will not be spilled on the skin or clothing. If fluxes do come into contact with the skin, the skin should be washed thoroughly with soap and water.
13. Eating or storing of lunches should not be permitted in the work area, and workers should wash both hands and faces before eating, smoking or leaving from work.

HANDOUT 8: SOLDERING AND BRAZING

CLEANING

After cutting and deburring, the tubing and fitting must be properly cleaned to remove dirt, oil, grease and oxides. First clean with a solvent and then use a fine grit emery paper to clean the fitting and the end of the tubing. Clean the fitting all the way down to, and including, the bottom of the socket where the ledge starts. Clean the tubing ¼ to ½ inch more than the depth of the socket, or 3/4 to 1 inch from the end of ½ inch diameter tubing. Do not remove more metal than is necessary to get a clean-looking surface. Do not handle surfaces after cleaning.

FLUXING

Flux protects the cleaned metal from oxidizing when the parts are heated, and should be applied immediately after cleaning. Fluxes generally used are available in paste form and can be applied sparingly in a thin, even layer to the tubing and fitting. Be sure to use a clean brush, and cover only those areas to be soldered or brazed. In the case of refrigeration joints, do not flux the inside of the fitting. Assemble the parts immediately after fluxing, making sure the tubing is inserted into the fitting until it bottoms out. Where, possible, revolve the fitting once or twice on the tubing to spread the flux uniformly.

SUPPORTING THE ASSEMBLY

After assembly and correct alignment, the assembly should be adequately supported so that expansion and contraction will not be restricted and there is not any strain on the joints.

HEATING AND FLOWING THE ALLOY

Start by using a torch tip that delivers a relatively small flame size; then a larger flame or even a multiple-tipped torch. Shorter heating periods may be used as proficiency improves. Adjust the torch for a slightly reducing flame. Heat the tubing first, directing the flame slightly away from the fitting. Try to keep the flame away from the fluxed and cleaned areas to minimize oxidation. After heating the tube momentarily, alternate the flame between the tubing and fitting. Do not melt the alloy or solder with the flame. It will melt by contact with the tubing when the proper temperature is reached. When the alloy or solder begins to melt, move the flame to the corner of the fitting, rotating it as necessary to heat the entire perimeter, and feed the alloy or solder into the joint all the way around the tube. Remove the flame once the joint is full. Overheating may damage the joint.

CLEANING

After the alloy or solder has set, apply a wet brush or swab to the joint to crack and wash off the flux. All flux

should be removed for inspection and pressure testing. Use a wire brush if necessary. Be careful not to move the assembly while the alloy or solder is solidifying, or a cracked joint will result.

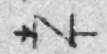
HANDOUT 9: SYMBOLS

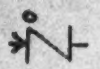
Schematic symbols for common items are shown below. Shorthand notations denoting how the plumbing connections are made have been omitted.

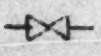
Elbow, 90 degrees

Elbow, 45 degrees

Tee


Check valve


Swing check valve


Gate valve

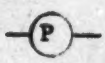
Globe valve

Pressure relief valve

Float-type air relief valve

Normally open solenoid valve

Normally closed solenoid valve



Pump

Thermostat switch

Resistor

Capacitor

Transformer

Relay coil

HANDOUT 10: VALVES

BACKFLOW PREVENTER--a double check valve with an atmospheric vent.

BALL--see common controllable valves.

CHECK--prevents reverse flow through the system.

COMBINATION TEMPERATURE/PRESSURE--automatically opens when it senses too much heat or pressure.

COMMON CONTROLLABLE VALVES--the most common controllable valves are the globe, ball and gate valves. The globe valve got its name from its globular body. It is used for control of liquids, gases, and vapors by means of throttling. In the home, this type of valve is most frequently found on main supply lines. The closure disk and seat permit close regulation of the amount of water passing through the line. The globe valve is designed to minimize erosion where a wide range of flow is desired. Globe valves offer more resistance to flow than a gate or ball valve. Gate and ball valves offer little friction to water flow and contribute negligible waterline pressure drop, providing the valve disk or stop cock is kept fully closed or fully opened. The ball valve is shut off when the hemispherical stop cock is rotated so that it blocks the flow. The gate valve contains a gatelike disk that is moved by a stem screw attached to the hand wheel. Normally, gate and ball valves should not be used for throttling. It may be impossible to throttle flow with a ball valve, but it can be managed with a gate valve.

FLOAT-TYPE AIR RELIEF--"bleeds" air out of the system and provides vacuum relief for draining.

GATE--see common controllable valves.

GLOBE--see common controllable valves.

ISOLATION--an in-line shut-off valve.

SNIFTER--has provisions for attaching an air pump hose to pressurize the system.

SOLENOID--a remote-control valve that can be opened or closed at command from a differential thermostat.

TEMPERING--mixes hot and cold water to regulate temperature.

HANDOUT 11: PUMPS

OPERATION

Thermosiphon solar systems rely on natural convection for circulation of water in the system. Other solar energy systems use circulation pumps to circulate the heat transfer fluid from the collector panels to the storage tank and to resupply the fluid back to the panels. If the collector is drained for freeze protection, the pump may also have to initially refill the system.

The pumps in solar systems are normally controlled by a differential thermostat which uses the heat sensors to measure the temperature of the fluid at the output of the collector and the temperature of the fluid in the storage tank. When the collector outlet temperature exceeds that of the storage tank by a specified amount, generally 15 to 20 degrees F, a relay closes starting the pump motor. The pump will continue to operate until the temperature differential decreases to 2 to 3 degrees F.

Two-speed or variable speed pumps with proportional control to vary RPM as a function of the temperature difference between the collector and the storage tank can be used to improve the efficiency in energy transfer.

PUMP HOUSING

In general, only pumps with stainless steel or bronze

water-touched surfaces should be used in "open" systems, and pumps with cast iron water-touched parts can be used in "closed" systems. Closed systems are defined as systems which continuously recirculate the same water and do not emit oxygen or fresh water into the system. Oxygen in "open" systems can rapidly deteriorate a pump with cast iron water-touched surfaces due to rust and corrosion build-up in the pump housing.

MAXIMUM FLOW AND HEAD REQUIREMENTS

Choosing the correct-sized pump requires determining the maximum flow and head requirements for the system. The flow rate through a collector loop is normally very low, typically 1 gallon per hour per square feet of collector area. Collector manufacturers normally specify the maximum flow necessary for maximum heat transfer into the storage tank, based on the isolation available for the particular area.

Pressure losses in a solar loop, referred to as feet of head, are the total loads placed on the pump by resistance to fluid flow through valves, fittings, solar collectors, horizontal lines, and, in open systems, the net vertical rise of the water, Manufacturers usually specify the losses in the collector and tables are available to calculate the other losses. Basically, the head in open systems is equal to the height (in feet) of the collectors above the pump plus a small allowance for other frictional losses.

Once the maximum flow and head requirements of the system are known, the proper pump can be selected from pump performance curves furnished by the manufacturer.

HANDOUT 12: AVAILABILITY OF SOLAR ENERGY

Solar radiation is a form of electromagnetic energy and includes X-rays, gamma rays, ultraviolet rays, visible light rays and infrared rays. As the sun's energy reaches the atmosphere, some is reflected away from the earth, some is scattered by constituents of the atmosphere and re-directed onto the earth's surface, and the rest moves directly to the earth's surface. As a result, the earth is exposed to both diffuse and direct radiation. The total radiation, referred to as insolation, falling upon the earth's surface varies greatly with place and time, and is one of the main considerations in selecting a system for a particular location.

Several types of solar radiation data are available for use in designing and evaluating the economics and performance of solar systems. The types of data that will be used in this unit are heating degree-days, average daily solar radiation on a horizontal surface, and clear-sky daily solar radiation versus slope and latitude. Specific values that will be used for design calculations in this unit are as follows:

Table I
Average Daily Solar Radiation on a Horizontal Surface (Langleys)
(for Unit design location)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
250	320	420	530	570	850	640	590	480	380	280	230	460

Table II
Heating Degree Days (Base 65 degrees F)
(for Unit design location)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1050	840	720	355	125	10	0	0	35	250	665	940	4990

Table III
Clear-Sky Daily Solar Radiation vs Slope and Latitude (BTU/ft^2/day)
(for latitude of Unit design location)

Day	Horiz	L-10	L	L+10	L+20	Vertical
Jan 21	1075	1730	1885	1985	2030	1745
Feb 21	1530	2110	2215	2255	2230	1700
Mar 21	1940	2335	2355	2310	2200	1406
Apr 21	2315	2424	2335	2185	1970	925
May 21	2565	2445	2270	2050	1770	630
Jun 21	2640	2435	2225	1980	1675	520
Jul 21	2545	2420	2235	2015	1735	610
Aug 21	2375	2395	2305	2155	1945	635
Sep 21	1870	2240	2280	2210	2105	1345
Oct 21	1460	2075	2115	2155	2135	1630
Nov 21	1070	1705	1855	1950	1990	1705
Dec 21	915	1565	1730	1845	1905	1700

HANDOUT 13: RESIDENTIAL HOT WATER REQUIREMENTS

For a typical family, two adults and two children, the daily hot-water use is:

Bathing	36 gallons
Dishwashing	16
Laundry	8
Cleaning	6
Miscellaneous (includes pipe losses)	20
Total	86 gallons

Water is typically used at the following temperatures:

Laundry	120 degrees F
Tub bath	100
Shower	100
Dishwasher	140

(Source: Residential Energy Consumption-Phase I Report, U.S. Department of Housing and Urban Development, Washington, D.C., Rept. HUD-HAI-1, Contract No. H-1654, Stock No. 2300-00262.)

In this Unit, the following assumptions will be used for design calculations:

Average cold water supply temperature from city mains equals average outdoor temperature (59 degrees F for design location).

Hot water service temperature is 140 degrees F.

Collector operates at an average efficiency of 55%.

Storage tank and plumbing line heat losses equal 12% of the solar energy collected.

The average family member uses 20 gallons of hot water per day.

An automatic clothes washer requires 20 gallons of hot water per day.

An automatic dishwasher requires 15 gallons of hot water per day.

HANDOUT 14: DESIGN CALCULATIONS

The following procedures offer simplified method of calculating the size of collector needed for a solar hot water system. The calculations are based on averaging conditions over the entire year rather than month-by-month calculations. Therefore, the system will not meet the total energy need. This is not all bad, however. For example, one detailed design study showed that for the particular application, a system that supplied 60% of the energy need was the best in terms of economic benefit.

Problem:

Calculate the size of collector required for a solar hot water system designed to meet the needs of a family of three with clothes washer and dishwasher. Use the data for the design location given in Handout 12, and the information contained in Handout 13.

Step 1. Calculate the Energy Requirement

The daily energy requirement may be calculated from the formula:

$$Q = G \times K \times \Delta T$$

where: Q = daily energy requirement (BTU/day)

G = gallons of water used per day

K = weight of water (8.345 lb./gal.)

ΔT = difference between use or service temperature and supply temperature

Thus,

$$G = (3 \times 20) + 15 + 20 = 95 \text{ gallons}$$

$$\Delta T = 140 - 59 = 81 \text{ degrees F}$$

$$Q = 95 \times 8.345 \times 81 = 64{,}215 \text{ BTU/day}$$

Step 2. Calculate the Solar Energy Available

From Handout 12, the average daily radiation on a horizontal surface at the design location is 460 langleys (Table I). Multiplying 460 by 3.69 to convert to BTUs yields 1697 BTU/ft^2/day. Using Table III for the latitude of the design location and assuming the slope of the collector is 10 degrees greater than the latitude (L + 10), the average ratio of the "L + 10" values to the horizontal values is 1.27. This average ratio is then used to provide a corrected value for the average daily solar radiation:

Average available solar energy = 1697 x 1.27 = 2155 BTU/ft^2/day

Step 3. Calculate Size of Collector

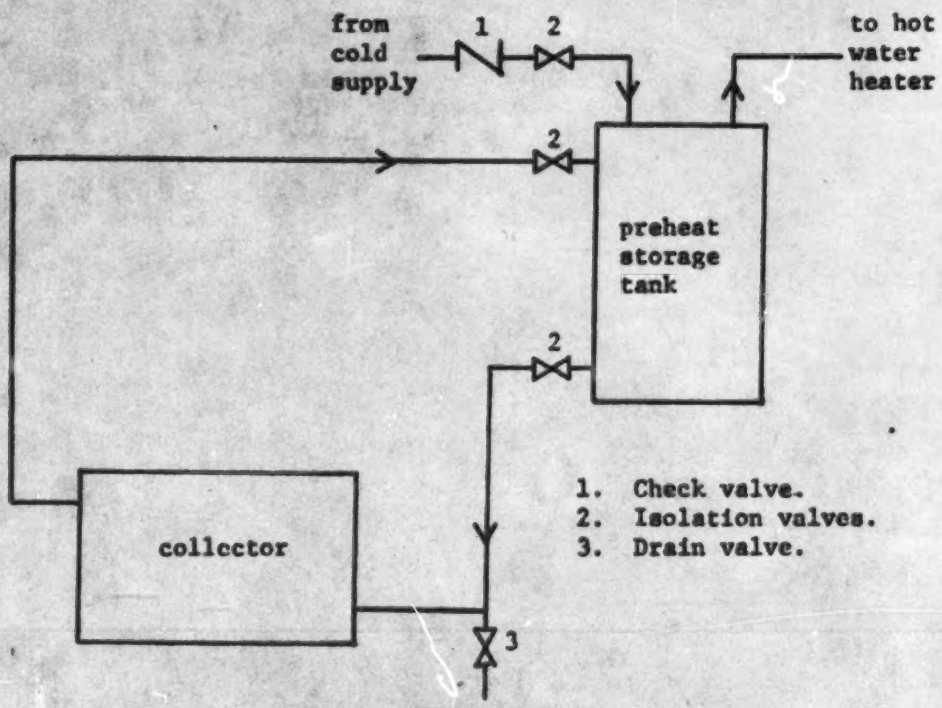
Assuming an average collector efficiency of 55% and that line and tank losses total 12%, the usable energy is:

Usable energy = 2155 x .55 x .88 = 1043 BTU/ft^2/day

To determine the square feet of collector needed, divide the average daily load by the usable energy:

Collector area = 64,215/1043 = 62 square feet

HANDOUT 15: DIRECT HEATING, THERMOSIPHON SYSTEM



OPERATION

The thermosiphon system is the simplest type of solar water heater to understand and build. The storage tank is located one to two feet below the bottom of the solar collectors. Water heated by the collectors flows upward into the storage tank and is replaced by colder water of greater density from the bottom of the tank. With proper design, this flow occurs without the aid of a pump and will not reverse at night when the collectors cool. Although this type of system is simple,

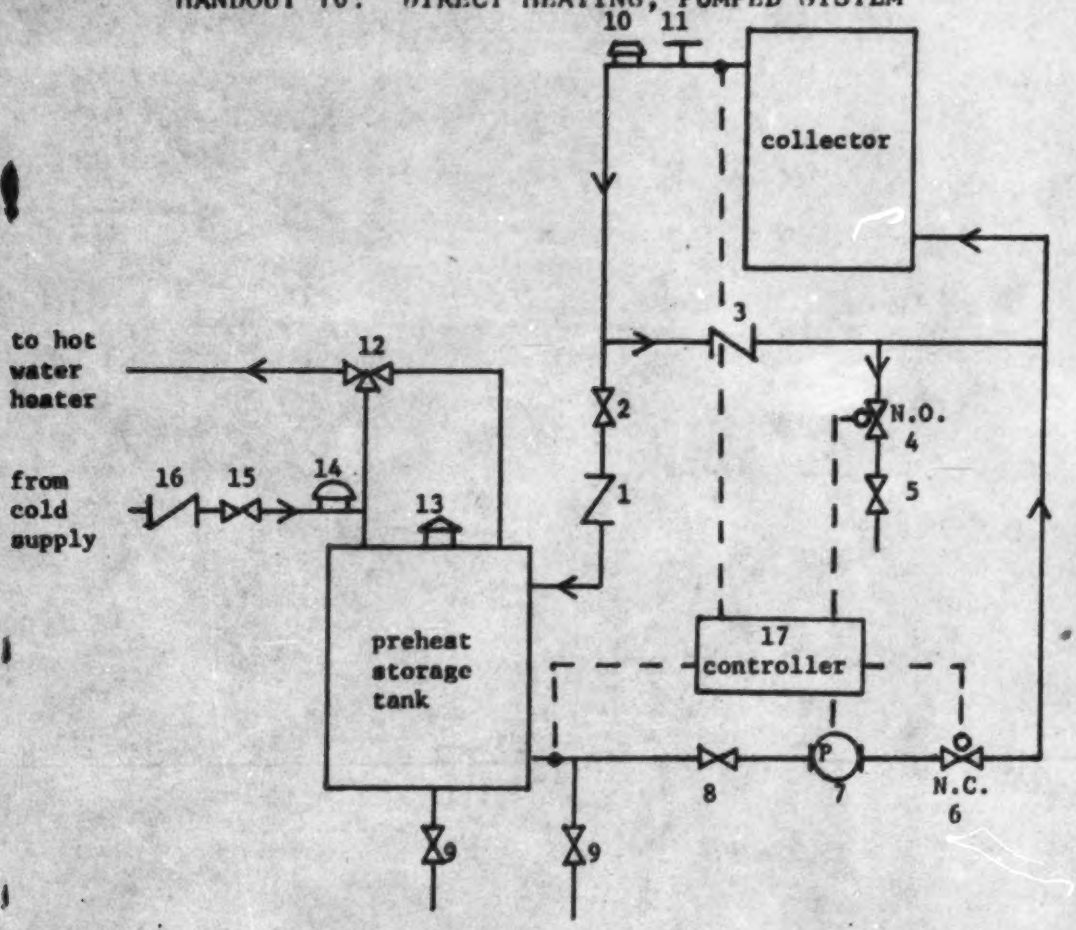
it does have a number of limitations:

1. There is no automatic freeze protection.
2. Placing the storage tank above the collectors sometimes means structural problems.
3. Impurities in the water can eventually cause mineral deposits to build up on the absorber tubes and plumbing.

PLUMBING

Feed lines to and from the collectors should be kept as short as possible, 10 feet or less per leg, and well insulated. All connecting lines should have a minimum slope of 0.25 in/ft toward the drain. There must be an absolute minimum of friction (use 1 inch or larger diameter lines with a minimum of bends and fittings). The combination temperature and pressure relief valve (150 psi, 210 degrees F) should have a drain line attached that terminates in a safe place to prevent scalding or property damage in case of discharge. The isolation or shut off valves, made of cast brass of the gate or ball type, are placed where the collector lines join the tank. The drain valve is installed at the lowest point in the plumbing. The check valve and shut off valve for the cold water supply may be required by local code or desired by customer or installer.

HANDOUT 16: DIRECT HEATING, PUMPED SYSTEM



1. Check valve prevents flow from the storage tank through the drain when the solenoid drain valve is open.

2. Flow control or balancing valve assures proper control of flow thru the collectors.

3. Check valve prevents "short-circuiting" flow thru the drain loop. When the pump is operating, the pressure on the pump side is high enough to keep this valve closed.

4. Two-way, normally open solenoid drain valve which allows the supply and return lines of the collector loop to drain when the frost sensor shuts off power to the valve.

5. Shut off valve for manually closing collector drain during summer operation.

6. Two-way, normally closed solenoid valve which prevents flow from the storage tank when the differential thermostat shuts off power to the pump.

7. Bronze or stainless steel circulator pump (1/12 to 1/25 hp is adequate for most installations).

8. Isolation or shut off valve.

9. Manual drain valves for the system.

10. Pressure relief valve (100 psi).

11. Combination vent-vacuum relief valve allows air to enter the lines to facilitate draining (150 psi rating, float operated).

12. Tempering or mixing valve to control outlet temperature for economy and safety (common setting is 140 degrees F).

13. Temperature and pressure relief valve (125 psi/210 degrees F).

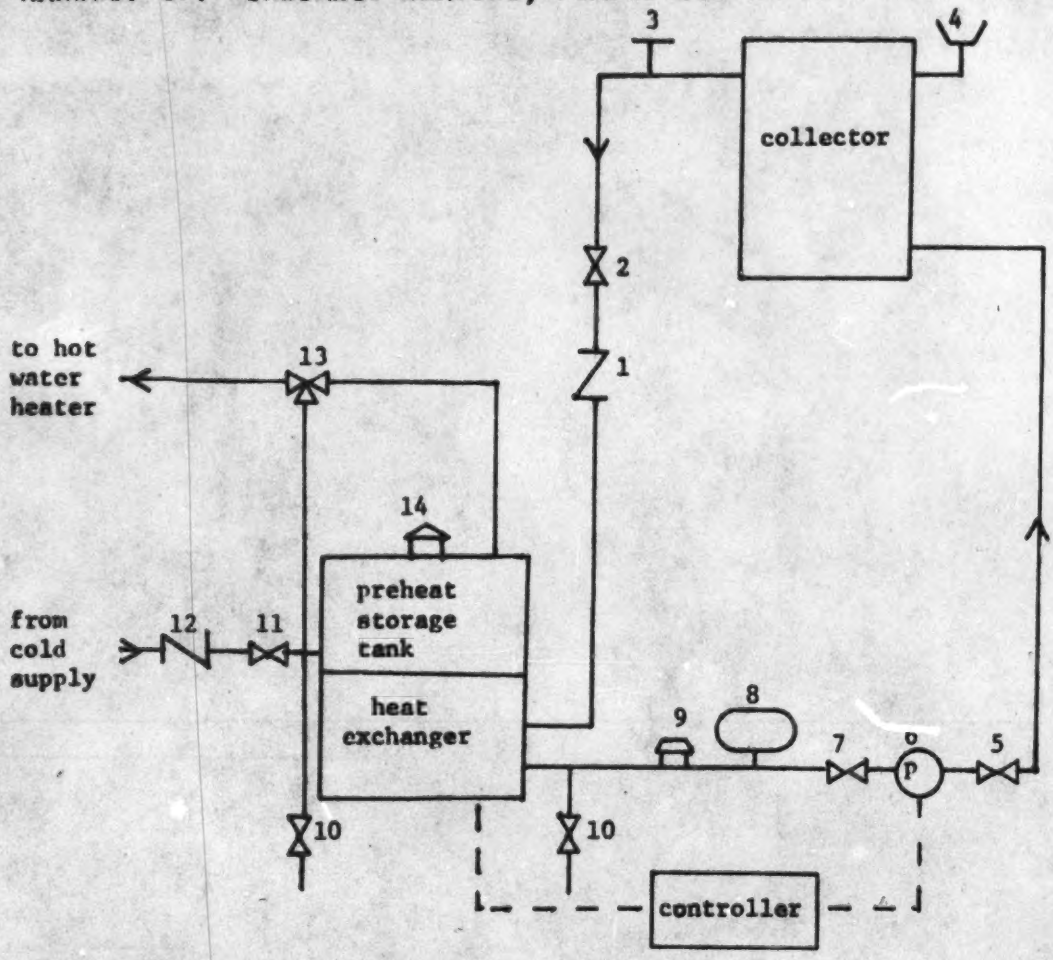
14. Vacuum relief valve alleviates a vacuum condition which can collapse the tank.

15. Isolation or shut off.

16. Check valve for cold water supply line.

17. Differential controller turns on pump, opens valve 6 and varies pump speed as a function of the temperature difference between the collector and storage. It also provides low temperature freeze protection by controlling valve 4.

HANDOUT 17: INDIRECT HEATING, PUMPED SYSTEM WITH HEAT EXCHANGER



1. Check valve to stop thermosiphoning when tank temperature is higher than collector temperature.
2. Flow control or balancing valve to assure proper flow control thru collectors.
3. Air vent to allow trapped air to escape.
4. Fill valve to manually fill the lines.
5. Isolation valve.
6. Cast iron circulating pump is suitable for closed loop system.
7. Isolation valve.
8. Expansion tank to allow heat transfer fluid to expand.
9. Pressure relief valve (30 psi) allows heat transfer fluid to escape if maximum pressure is exceeded.

10. Drain valves.

11. Isolation or shut off valve.

12. Check valve for cold water supply line.

13. Mixing or tempering valve to control outlet temperature for economy and safety (common setting is 140 degrees F).

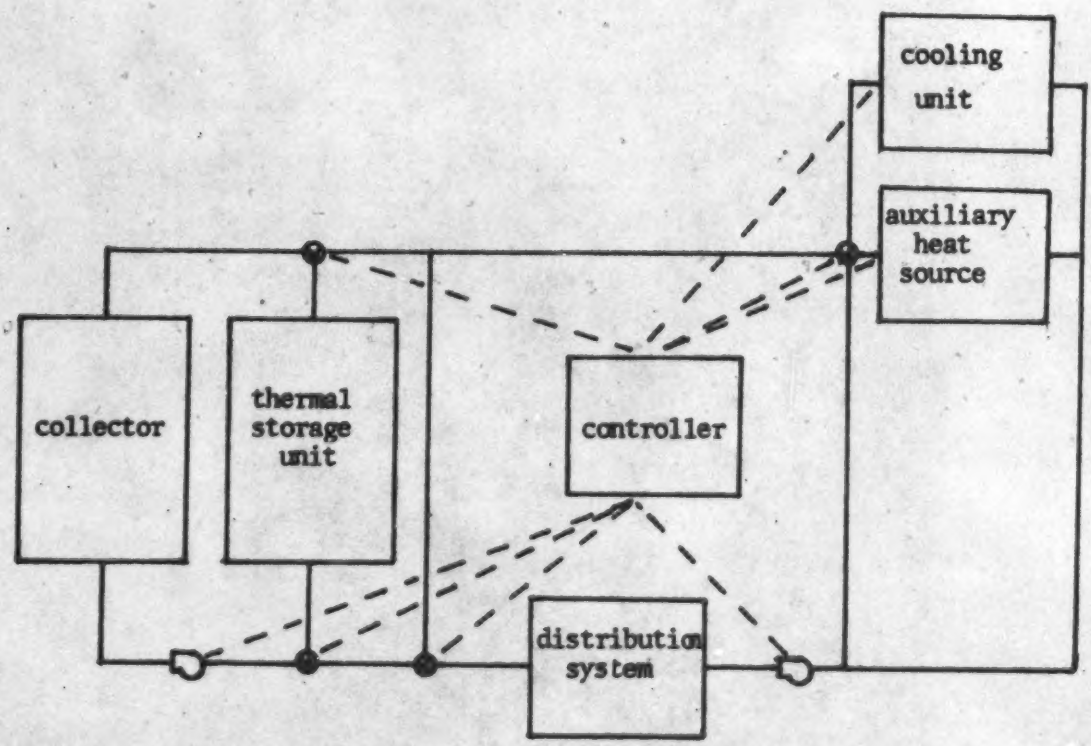
14. Temperature and pressure relief valve (125 psi/210 degrees F).

HANDOUT 18: ACTIVE SOLAR HEATING AND COOLING

There are six main elements common to most solar heating and cooling systems:

1. collector
2. thermal storage unit
3. auxiliary heat source
4. cooling unit
5. distribution system
6. control devices and speciality items

A simplified schematic representation of an active system is shown below.



SOLAR COLLECTOR

The type of device used to collect solar energy depends primarily on the application. Concentrating collectors are used to focus the direct radiant energy onto a smaller absorber area. They have the advantages of high temperature heat collection, high collection efficiency and compact heat storage. However, they are expensive to construct and operate, and they do not function well on cloudy or overcast days.

Flat plate collectors are commonly used for space and domestic hot water systems, and they can provide temperatures as high as 150 degrees F above ambient. The majority of flat plate collectors have five main components:

1. a casing or container which encloses the other components and protects them from the weather
2. insulation which is used to minimize heat losses
3. a transparent cover consisting of one or more sheets of glass or heat resistant plastic
4. an absorber plate, normally metallic with a black finish, although a wide variety of other materials can be used, particularly with air heaters
5. fins, tubes or passageways integral with the collector absorber plate or connected to it, which carry the water, air or other heat transfer fluid.

THERMAL ENERGY STORAGE

Thermal energy storage is essential for both domestic water and space heating applications. The storage units

normally operate independent of any cooling or heating requirement since they can be storing solar energy whenever there is sufficient solar radiation. Materials for storing energy can be liquid, rock or phase change mediums. Water and rocks are typical examples of materials which store energy as specific heat (sensible heat), but their use is limited by their comparitively low specific heats (1 and 0.2 BTU/lb per degree F respectively). An alternative to the sensible heat system is a latent heat storage system. The heat of fusion (latent heat) which is involved when a storage medium changes state from a solid to a liquid provides a method of storing a given amount of heat within a smaller volume. Both sensible and latent heat storage systems have their advantages and disadvantages, and the selection of a storage medium is based on the ability of the substance to accept heat, the availability of the substance, safety and cost.

AUXILIARY HEAT SOURCE

Auxiliary energy is needed to supplement the solar system whenever the heat being collected and the heat from storage are below the demand or use temperature. While it is theoretically possible to construct a solar system that can meet total needs, it is generally not as economical as an auxiliary assisted system.

COOLING UNIT

Although solar assisted space cooling systems are currently in operation, they are very expensive relative to conventional systems. This may change in the next several years as research and development in the area continues. The methods commonly used for cooling include: evaporative cooling with storage for arid or semi-arid regions; a vapor-compression refrigeration system or heat pump driven by a solar powered engine; and absorption cooling with water as the refrigerant and lithium-bromide or ammonia as the absorbent.

DISTRIBUTION SYSTEM

Depending upon the system selected for solar heating and cooling, a common or a separate distribution system may be required. Air systems usually have a blower and duct distribution capable of using heat directly from the collector, storage unit or auxiliary system. In some liquid systems, the liquid is piped directly to the space to be heated or cooled and fan coil units are used to heat or cool room air.

CONTROL DEVICES AND SPECIALITY ITEMS

In addition to the five major units, there are a number of components that are equally important to the operation of the system. These include pumps, blowers, valves, dampers, controllers, heat exchangers, differential thermostats, sensors, etc. The controllers may be of the conventional

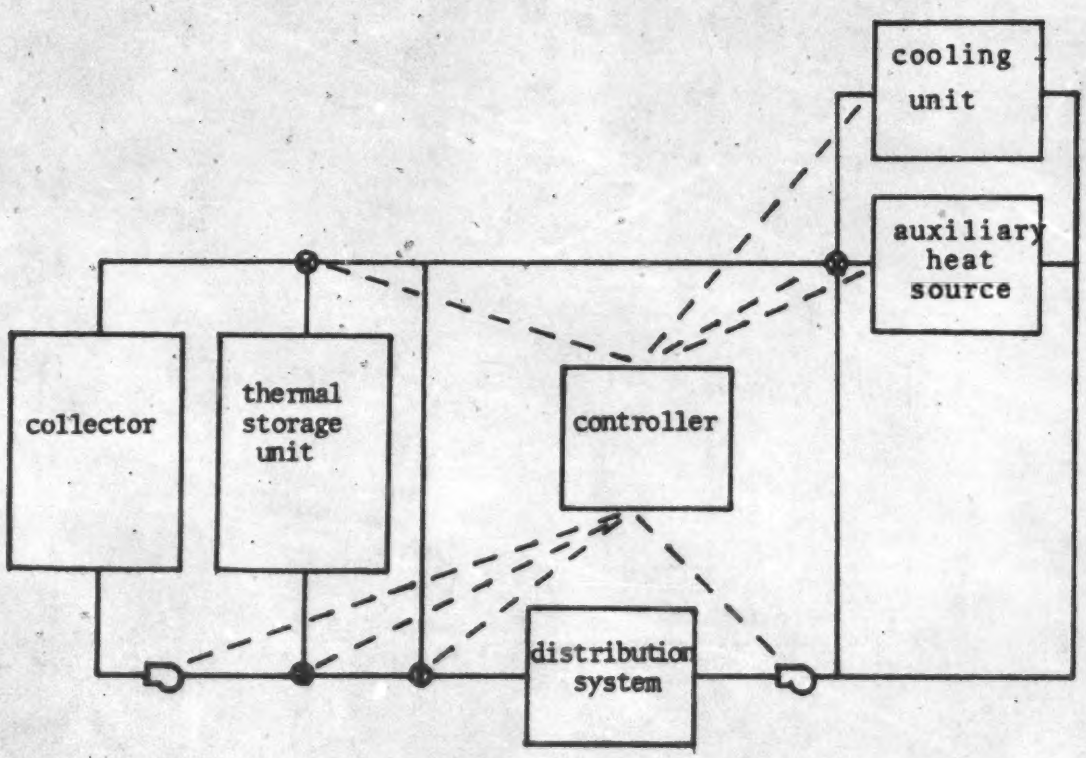
electromechanical type or solid-state. The controller normally includes a sensor subsystem for measuring temperatures, and a comparator subsystem for making decisions regarding the control of output devices, such as turning on and off blowers and pumps and the opening and closing of valves and dampers.

HANDOUT 19: COMMON OPERATING MODES

There are a variety of methods and devices for controlling the collection, storage and usage of solar energy. Common operating modes for an all-air system include:

1. direct space heating from the collector
2. space heating from storage
3. storage of heat from the collector
4. space heating from auxiliary unit
5. space cooling

The following figure is used to illustrate the five modes of operation.



SPACE HEATING FROM THE COLLECTOR

Heating directly from the collector occurs when the collector temperature exceeds the demand temperature, and the room temperature is less than the demand temperature. The flow pattern from the figure is 1, 2, 3, 4, 7, 8, 9, 10.

SPACE HEATING FROM STORAGE

Heating from storage occurs when the collector temperature is below the demand temperature, the storage temperature is greater than the demand temperature, and the room temperature is less than the demand temperature. The flow pattern is 2, 3, 4, 7, 8, 9.

STORAGE OF HEAT FROM THE COLLECTOR

Heat storage occurs when the airspace does not require heat and the collector temperature exceeds storage temperature. The flow pattern is 1, 2, 9, 10.

SPACE HEATING FROM AUXILIARY UNIT

Space heating from the auxiliary heating unit occurs when the airspace requires heat, and the demand temperature exceeds both the collector and the storage temperature. The flow pattern is 3, 4, 6, 7, 8.

SPACE COOLING

The flow pattern for space cooling is 3, 4, 5, 6, 7, 8 or 2, 3, 4, 5, 6, 7, 8, 9, depending on the type of system.

HANDOUT 20: COMMON PROBLEMS

Common problems associated with solar energy systems are listed below.

1. Inadequate calculation of energy requirements and the use of inaccurate weather data
2. Inadequately insulated pipes and ducts
3. Malfunctioning controls
4. Worn drive belts
5. Leakage in antifreeze loops
6. Leaky valves and dampers
7. Debris caught in the air vent
8. Freeze-ups due to diluted antifreeze solution or failure of draindown system to drain completely
9. Noise from solenoid control valves
10. High power consumption from inadequate ductwork or oversized fans
11. Improper connections to storage tanks
12. Incompatibility between heat transfer fluid and seals and gaskets
13. Overheated collector causing damage to collector and nearby components or building materials
14. Not taking into account the properties of heat transfer fluid when sizing expansion tanks and pumps
15. Corrosion in plumbing and components
16. Unbalanced system
17. Physical condition of the collector
18. Pumps not lubricated as specified by manufacturer
19. Failure to periodically change air and liquid filters
20. Low level of fluid in closed-loop collector systems